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ABSTRACT

In this report, the National Information Infrastructure (NII) services issue is addressed, and activities to advance the development of NII services are recommended. The NII is envisioned to grow into a seamless web of communications networks, computers, databases, and consumer electronics that will put vast amounts of information at users' fingertips. Crucial to the development of an advance information infrastructure is the concept of NII "services," which manage the orderly flow of data and enable support applications. Many experts believe that the most critical aspect of the NII is the development of a services infrastructure; without it, access to the NII's advanced capabilities may be extraordinarily difficult and my not be affordable by the average citizen. An ongoing process of research, development, experimentation, and public debate, combined with commercial development and product deployment, is required to evolve a services framework and implementation.The Technology Policy Working Group recommends that: (1) high priority support continues to be needed in the 5 year strategic planning process the Committee on Information and Communications (CIC) is currently pursuing; (2) the coordinated government-wide R&D strategy for NII services which is under development by the CIC should continue to be closely coordinated and integrated with the progressive technology acquisition and deployment strategy being developed and implemented by the Information Infrastructure Task Force (IITF); and (3) government, industry, and academia should work closely together in pursuit of an advanced architectural framework for the NII services layer that supports interoperability while enabling individual commercially competitive solutions. Appendices include: "Representative High Performance Computing, Communications, and Information Technology's Information Infrastructure Technology and Applications (IITA) Tableau of Services" and "NII Forum--R&D for the NII: Technical Challenges, Services Research Recommendations." (MAS)

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Services and the National Information Infrastructure

Technology Policy Working Group
Committee on Applications and Technology
Information Infrastructure Task Force

December 2, 1994

ACKNOWLEDGEMENT

This report, prepared by the Technology Policy Working Group (TPWG) for the Committee on Applications and Technology (CAT) and the Information Infrastructure Task Force (IITF), summarizes a set of conclusions and recommendations synthesized from the contributions of many individuals. Each of the individuals that contributed directly and indirectly to each of the principal references listed in the appendix are hereby acknowledged and their contribution is appreciated.

Of special note are the efforts of the TPWG Services Architecture Subworking Group (SASG) that labored long and hard to understand and put in perspective the NII services area. This group was led by Dr. Shukri Wakid from the National Institute of Standards and Technology (NIST). The SASG, consisting of individuals drawn from NIST, the Defense Information Systems Agency (DISA) and the National Aeronautics and Space Administration (NASA) with contributions from the Advanced Projects Research Agency (ARPA) and the National Security Agency (NSA) helped define a framework for NII services. This view, complemented by those taken by the Cross-Industry Working Team (XIWT), the Computer Systems Policy Project (CSPP), the Computer Science and Telecommunications Board, National Research Council (CSTB/NRC), and the many academic, industry, and government participants who contributed to the "R&D for the NII: Technical Challenges," a symposium held on February 28 and March 1, 1994, did much to further understanding of what is meant by the services layer and what is needed for a successful NII.

December 1994

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DRAFT FOR PUBLIC COMMENT

Services and the National Information Infrastructure

Report of the Technology Policy Working Group, Information Infrastructure Task Force Committee on Applications and Technology

Executive Summary

The National Information Infrastructure (NII) is envisioned to grow into a seamless web of communications networks, computers, data bases and consumer electronics that will put vast amounts of information at user's fingertips.[1] Crucial to the development of an advanced information infrastructure is the concept of NII "services." Services manage the orderly flow of data and enable support applications. They are the "glue" that connects the physical network and computing infrastructure with the applications that serve users' needs.

From the consumer's point of view, the capabilities provided by NII services allow users to:

- search, discover, update, transform, and retrieve useful information;
- build and maintain electronic repositories of information;
- create and distribute information electronically;
- execute and record commercial, legal, financial, and other business transactions; and
- support collaborative work efforts among collocated or remote individuals.

A pacing factor for the development of an advanced NII is the interoperability and scalability of the services that are implemented within the infrastructure. Many experts believe that the *most* critical and difficult to realize aspect of the NII is the development of a services infrastructure. Without a coherent services infrastructure, access to the NII's advanced capabilities may be extraordinarily difficult and may not be affordable by the average citizen.

No single authority (including the government) has either the knowledge or span of control to develop, mandate or legislate a coherent services framework within which individual commercial competitive solutions can coexist and interact. An ongoing process of research, development, experimentation and public debate is required. This should be combined with commercial development and product deployment to evolve a services architectural framework and its implementation. Government should provide the leadership and vision to guide this process, to balance the interests of the many NII stakeholders, and to influence the shape of the information infrastructure.

Several major organizations within the Executive Branch are working together closely to develop, coordinate, and implement research and development (R&D) strategies and policies in support of the Administration's NII initiative. The National Science and Technology Council (NSTC) is a permanent, cabinet-level body, chaired by the President of the United States, which prepares R&D strategies that are coordinated across Federal agencies.

NSTC, operating through the Committee on Information and Communications (CIC), is responsible for R&D technology policy, strategic planning, and interagency coordination related to information and communications technologies. It leads the Federal R&D community in its support for National and Global Information Infrastructure technology developments. The CIC oversees the Federal High Performance Computing and Communications and Information Technology (HPCCIT) initiative, which is developing the technologies needed for dramatic improvements in information services for the future NII.

The Information Infrastructure Task Force (IITF), chaired by the Secretary of Commerce, was created by the Office of Science and Technology Policy (OSTP) and the National Economic Council (NEC) to ensure that the entire Federal Government acts in concert to accelerate deployment and use of the NII. The Technology Policy Working Group (TPWG) of the Committee on Applications and Technology (CAT) is designated to work with the technology development community to serve as a catalyst to promote technological innovation, to stimulate the private sector to develop and adopt technologies for a highly capable NII, and to identify and reduce barriers to implementation. Considerable coordination exists between activities of the CIC and the TPWG, and in fact many of the key players actively support both organizations.

In this report, the services infrastructure issue is addressed, and activities to advance the development of NII services are recommended. The Technology Policy Working Group recommends that:

• **Recommendation 1: The Federal Government, through the NSTC/CIC, has placed considerable emphasis on R&D for future NII services. High priority support continues to be needed in the five year strategic planning process that the CIC is currently pursuing.**

High priority NII R&D areas that should be addressed are:

- ease of use to make services accessible by users with widely varying skills, experiences, abilities and backgrounds;
- interoperability among heterogeneous services;
- security and privacy technologies to provide cost effective, easy to use services at appropriate levels of security; and

- portability, mobility and ubiquity to enable users' access independent of location.

This R&D would involve advancing the state of technology in such areas as: data and knowledge management, multimedia search and retrieval, human-computer interfaces, language translation, and object technology.

- **Recommendation 2: The coordinated government-wide R&D strategy for NII services which is under development by the CIC should continue to be closely coordinated and integrated with the progressive technology acquisition and deployment strategy being developed and implemented by the IITF.**

The NII services strategy should include the development of pilot applications built on common services that address government problems with significant relevance to the private sector. Development of the services strategy should be via an open process and involve the widest possible industrial and academic communities. The government should encourage and cooperate with industry to advance dialog and activity on creating a coherent services infrastructure.

- **Recommendation 3: Government, industry, and academia should work closely together in pursuit of an advanced architectural framework for the NII services layer that supports interoperability while enabling individual commercially competitive solutions.**

Introduction

> "In the beginning, computers were shipped empty. Each program written for it was loaded independently and occupied the entire machine when it ran. Gradually it became clear that there were common functions used by all programs that ought not be re-written for each new one. They could more productively be included in a common underlying operating system for that machine. This operating system is thus the infrastructure on which we build our current applications."[2]

Today, "computer" is an inadequate description of the systems that connect people to the NII and provide its services. Computers were once thought of as calculating devices. Now, computers linked by communication systems have become information and knowledge providers. These devices are more aptly termed "information appliances" and "information servers." They support communications, information storage, user interactions, and incidentally compute.

Information infrastructure technology is changing the way that individuals and organizations work and is restructuring traditional end user-supplier relationships. The technology has the potential of offering a new range of products and services that are far more powerful than those which are currently available. Achieving this potential as rapidly as possible will maintain and extend the nation's competitive edge.

The NII must accommodate a wide variety of users and service providers. This includes end users, service/product suppliers, and builders of applications and services. The relationship between supplier and user is becoming much more complex than in earlier periods. There are no longer neat consumer-supplier relationships. Users have become suppliers and suppliers users, as each adds value by packaging existing products along with their own offerings to create new products and services.[3] For example, a "user" might be a software reseller, an integrator, or a publisher. In each case, the user would receive data or software from another, process the material, and transfer it to others in the distribution cycle where the process might be repeated. The NII must also support fact finding by courts, administrative law judges, and mediators who will be called upon to resolve disputes among the users and service providers.

In the near future, the infrastructure will be required to support new applications which possibly must search many large information repositories. Customers and suppliers, using a new generation of information appliances, will access these repositories through high speed networks. A new generation of advanced communication and information access services will be required.[4]

NII Services - A Vital Element of an Advanced Infrastructure

Crucial to the development of an advanced information infrastructure is the concept of NII "services." This concept can be understood best in the context of an NII model which has received widespread recognition.[2] The model consists of three major interconnected layers: **"Network Bitways," "Services,"** and **"Applications."**

The **"Bitways"** are the physical infrastructure—the collection of transmission channels such as fiber, cable, satellites and broadcast links, switching devices and computers which interconnect the channels into coherent communications and computing systems. The **"Applications"** layer represents the capabilities provided to the end user to address specific applications such as providing health care, manufacturing a product, dealing with a crisis, or educating a class of students.

The **"Services"** layer is composed of those elements of the infrastructure that enable applications or manage the orderly flow of data through the system. Each of the three layers sustains a diverse base of technologies, supports a broad base of suppliers, and can continually increase in capability over time.[5],[6]

Services are the glue between the physical **"Network Bitways"** and the **"Applications."** Services provide data that can be accessed and shared by more than one application. Services manage the flow of data in the bitways, provide building blocks for applications, and provide the interfaces for displays, sensors, and other input/output devices. NII services provide capabilities for electronic creation and diffusion of information needed to satisfy a diverse set of applications. From the user's point of view, the capabilities provided by NII services center on:

- searching, discovering, updating, transforming, and retrieving useful information;
- building and maintaining electronic repositories of information;
- creating and distributing information electronically;
- executing and recording commercial, legal, financial, and other business transactions; and
- supporting collaborative work efforts among collocated or remote individuals.

From a supplier's point of view, NII services:

- enable new application product offerings without requiring the creation of all of the supporting software;
- facilitate the encoding and transport of data between locations and between networks;
- translate data from one language representation to another; and

- support the migration of existing data files, data bases and programs from older legacy systems to more modern systems.

A service will often originate as part of an application then become generic. For example, electronic mail was initially an application. Gradually, the directory, addressing and routing functions separated from the interface and became part of the network services while the interface became the next generation application. Similarly, methods to include sound, programs and images in E-mail began as application-specific elements and are gradually becoming services.

Interoperability within the services layer is a pacing factor in developing an advanced NII. The presence or absence of interoperability between services will determine whether users or developers must rebuild basic service elements as new applications are developed, or, alternatively, whether a standard set of interoperable, off-the-shelf services can be used to create new applications. A report published by the Cross-Industry Working Team (XIWT) contained the following observations about applications and services and their relationships:[2]

- Applications will often span more than one domain. For example, a personal planner/organizer application can encompass finance, travel and restaurants.

- Applications will often be built on top of other applications, which in turn, may be composed of still other applications.

- An application, that is originally written for one or two parties, can evolve to a service, as more people and organizations begin to use it.

- Services can either be shared by several applications or be specific to a single application.

- The aspect of the NII that is critical and most difficult to realize is the development of a services infrastructure.

Services support a variety of activities. Some help users to move and navigate between different networks and information resources. Others simplify applications programming by hiding many of the lower level systems details from the developer. Still other services provide directories such as shopping catalogs, electronic yellow pages, on-line digital libraries, and on-line airline flight information.

The NII must have built-in privacy safeguards to allow individuals and companies to conduct business with the confidence that data and information are private, authentic, and secure. The services layer must therefore also include services that implement

privacy and trust mechanisms as well as defensive software organized to protect the infrastructure from intrusion and attack.[5]

The TPWG, in cooperation with the National Institute of Standards and Technology (NIST) and seven private sector organizations, cosponsored a symposium on "R&D for the NII: Technical Challenges" on February 28 - March 1, 1994. This "NII R&D Forum" was attended by more than 300 industry, university and government technology experts who discussed the technical research issues that need to be addressed in the development of an advanced NII. The results of the workshop are documented in a report entitled "R&D for the NII: Technical Challenges." The NII R&D Forum identified a series of broad technical challenges for developing an information infrastructure with requisite functionality and performance. Services-related challenges, which must be solved to enable business and individuals full access to the future NII, appear throughout the document and can be summarized as follows [4]:

- The services provided by the information infrastructure must be accessible by users with widely varying skills, experiences, abilities and backgrounds.

- Interoperability among heterogeneous systems is required on an unprecedented scale.

- Security and privacy technologies must be easy to use and must provide appropriate levels of security to suit the requirements, cost constraints, and convenience of the end user.

- Information access techniques must enable efficient searches of large distributed information repositories and make a myriad of information resources understandable.

- Multimedia information technologies, including real-time delivery of voice and video, or search and retrieval based on image content rather than textual attributes, must be integrated into information access services.

- Portability, mobility and ubiquity are special technical challenges for the information infrastructure. The NII utility must be as widely available as today's telephone services. Users must be able to move from site to site and still access the NII at either end point or while in transit.

The R&D for the NII Forum's services-related recommendations are identified in Appendix 2. No organization has defined the full range of services that will be required in the NII. However, a number of the services that will initially be required to populate the services layer have been identified. For example, Table 1 tabulates some of the

critical services areas under study by various segments of the research community.[2],[4],[5],[6],[7],[8]

Table 1
Representative Critical Services

• **Data and knowledge management** - Knowledge-based search and retrieval - Distributed transaction management - Information resource self-description - Bulletin board and directory services	• **Translation/interchange** - Data format conversion services (including multimedia) - Electronic Data Interchange (EDI) - Electronic Currency Exchange
• **Core Networking Management** - Identification Namespace Management Address Management - Finding/network resource location - Core communications services Transport/Encoding Internetworking/Rate Adoption	• **Security/Protection** - Authentication - Information Integrity - Confidentiality/Encryption - Access Control - Non-repudiation - Digital Signature

Other services include billing, capacity management, and "policy based" routing. Services such as those listed above would support the NII and enable many advanced capabilities such as:

- the ability to anticipate a user's needs and assist the user to formulate requests;
- rapid content relevant access to globally dispersed multimedia data bases; and
- the ability to search large, mobile and distributed information resources and to then extract relevant data in appropriate format and amounts.

Why a Coherent Services Architecture is Essential

A key impediment to the growth of the NII is the time and cost required to develop applications. While developers have shortened the development cycle by building software that is more modular, reusable and interoperable, the dream of being able to

develop software efficiently is far from realization. An even more difficult problem will be to interface newer applications with the older, legacy applications.[2]

A problem of even greater proportions arises in the aftermath of the explosive growth of applications and services made possible by the propagation of computing and communications. This is the prospect that the NII may develop in a fashion that allows developers to create multiple systems and applications that cannot interoperate. As a result, most users would find it extremely difficult to find and use NII applications. End users would be required to develop the skills of computer programmers and information infrastructure pilots to find and use data, information, and services. This gloomy prospect would defeat the goal of an open infrastructure usable by all of our citizens. It would block access for many, reduce utility for others and require substantially greater efforts and development of computer related skills than can be expected of the general population. Equally threatening, the cost of dealing with non-interoperable systems could make the NII not affordable for many of our citizens.

The HPCCIT's Subcommittee on Information Infrastructure Technology and Applications (IITA) supports the development of technologies needed for dramatic improvements in information services for the future NII. According to their report, services "will form the basis of the ubiquitous 'Information Web' of the 21st century."[5] To achieve this ubiquity, industry needs to evolve an open services architecture that supports the required capabilities. In this way, the benefits of an advanced NII will be available across our society. The challenge is to develop an architecture which can survive technology changes, allows insertion of new technology at any point in the architecture, and makes services accessible and affordable by non-technical users.

Evolving a Services Architecture

Evolving a widely accepted architectural framework for an NII services infrastructure is a critical challenge. The framework serves as an enabler for the introduction and use of applications. With it, vendors would be able to offer their applications without having to rebuild the supporting software infrastructure. Users would be able to gain access and utility without having to acquire an extensive education in computer sciences or having to build custom links between applications. Defining the essential services and providing the hooks and mechanisms for services to exist, evolve, and interoperate are difficult problems at the forefront of the research agenda.[6],[8]

The CIC, in its strategic planning process, is placing considerable emphasis on NII services and the technologies underlying them. Substantial efforts in defining some of the services required for the NII have been made by the HPCCIT for a series of major application areas termed "National Challenges." These application areas include crisis management, health care, manufacturing, education, and government services. For

example, in the HPCCIT's IITA focus area, the HPCCIT has defined a set of service classes which include:

- Universal Network Services,
- Integration and Translation Services,
- System Software Services,
- Data and Knowledge Management Services,
- Information Security Services, and
- Reliable Computing and Communications Services.

These are detailed in Appendix 1. However, while there is a substantial correlation between this work and the research suggestions made by the NII R&D Forum and others, there must be a more general industry discussion of these characterizations of services and their applicability to the overall problems of the NII.

Another NII services related effort has been undertaken by the Object Management Group. The Group, with over 400 industrial members, has developed an "object" representation of programs and data documented in its Object Management Architecture Guide.[9] This architecture addresses issues involved in defining objects, encapsulating them in appropriate ways, and specifying how the objects can communicate.

While "object" technology is seen by numerous groups as the next important step in information systems development, its least understood elements are scalability, security, communications, and interoperability.[4] Significant research issues have been identified by the NII R&D Forum in object system foundations, application construction tools, repositories, object brokers, license and payment mechanisms, and release and maintenance.

The Computer Systems Policy Project (CSPP), a group of thirteen computer systems suppliers, addressed the interoperability problems related to services but did not examine the overall services architecture issue.[10] The CSPP spelled out required interfaces in four areas: information appliance to network, appliance to application, application to application, and network to network. The group emphasized that "openness of these interfaces is essential to allow users to transmit information, enable wide access by users and providers, and stimulate competitive markets for NII products and services. The CSPP recommended that "industry lead the development of standards for interoperability while creating an interindustry forum on interoperability."

Similar conclusions were reached by an entirely different group made up of representatives of five industry organizations representing the entertainment, electronics, computer and communications industries. This group, in a workshop cosponsored by the TPWG and NIST, was assembled to study the role of advanced

digital video in the NII.[11] The group concluded that there is a need for a long-term program involving government and industry to:

- facilitate interface standards;
- address intellectual property rights and information protection; and
- fund research and development in interoperable systems.

The workshop concluded that additional standards are needed for one- and two-way communications; multicast video services; and internetworking cable, satellite, broadcast, common carrier and packaged media. Standards should address the interconnection and interoperability of digital appliances and devices, digital networks and channels, software and programs, and third-party services. Creating these standards requires identification of reference points (physical, management, and logical) and interfaces.

The desirability of an overall services architecture was recognized by the National Research Council's NRENAISSANCE Committee.[12] Its report, "Realizing the Information Future," recommended that *"The government must support research into general and flexible architecture as a keystone of its NII research. "* The report called for additional research in key middleware services (such as navigation and filtering), including models for organizing and exploiting on-line information, models for managing intellectual property rights, and a framework for electronic commerce. It cited issues in middleware and information services support as being less mature than those in other components of information networking.

There is strong industry, academic, and government endorsement for additional research and development in NII services and architecture. Two principles which are implicit in all of the recommendations were explicitly stated by the XIWT. These appear self-evident, but deserve emphasis:

- A services architecture should support a healthy competitive environment that encourages continuous innovation and improvement.

- The architecture should enable competing services to coexist, many with the same functionality, some designed to have generic applicability, and some targeted to a specific application domain.[2]

The implication of these principles, given the distributed nature of the NII's development, is that no single authority (including the government) has either the knowledge or span of control to develop, mandate or legislate a services architecture. What is needed is an ongoing process of research, development, experimentation, and public debate, combined with commercial development and productization to evolve a services architecture and its implementation.

The Role of Government

There is broad consensus about the general importance of services for the NII, some specific near term services that should be developed, and the long-term need for a services architecture. There is also strong agreement about the role of government.

Several major organizations within the Executive Branch are working closely together to develop, coordinate, and implement R&D strategies and policies in support of the Administration's NII initiative. The NSTC, chaired by the President of the United States, prepares R&D strategies that are coordinated across Federal agencies.

NSTC, operating through the CIC, is responsible for R&D technology policy, strategic planning, and interagency coordination related to information and communications technologies, and it leads the Federal R&D community in its support for National and Global Information Infrastructure technology developments. The CIC oversees the HPCCIT initiative, which is developing the technologies needed for dramatic improvements in information services for the future NII.

The IITF, chaired by the Secretary of Commerce, was created by the Office of Science and Technology Policy (OSTP) and the NEC to ensure that the entire Federal Government acts in concert to accelerate deployment and use of the NII.[1] The TPWG of the Committee on Applications and Technology has been designated to work with the technology development community to serve as a catalyst to promote technological innovation, to stimulate the private sector to develop and adopt technologies for a highly capable NII, and to identify and reduce barriers to implementation. Considerable coordination exists between activities of the CIC and the TPWG, and in fact many of the key players actively support both organizations.

The NII R&D Forum recommended a federal research and development program that complements commercial efforts in a way that stimulates and catalyzes further investment from industry.[4] The CSPP[10] believes that the Federal Government can best support private sector efforts by:

- refining and promoting the vision for the NII and developing a government -industry public interest partnership to oversee its implementation;
- funding research and development on pre-commercial technologies;
- investing in pre-commercial demonstration projects; and
- supporting an industry-led strategy to insure interoperability.

As previously indicated, the NRENAISSANCE Committee[12] recommended that:

- Government must support research into a general and flexible architecture as a keystone of its NII research.

- Government should focus its own investments and policy making to gain the maximum leverage and to assure the necessary balancing of interests to make sure that the public interest is met.

- Government's role is to provide leadership and vision, balance interests, air competitive differences, and influence the shape of the information infrastructure.

The Technology Policy Working Group agrees with the above conclusions and recommendations. The TPWG's recommendations, which are given in the following section, are consistent with the above points.

Recommendations

The Technology Policy Working Group concurs with the recommendations of the NII R&D Forum and with the NRENAISSANCE Committee in that the government must support research into NII architecture as a keystone of its NII research. The government should provide leadership and vision and focus its own investments and policy making to gain the maximum leverage to influence the shape of the information infrastructure. The TPWG's recommendations are:

- **Recommendation 1: The Federal Government, through the NSTC/CIC, has placed considerable emphasis on R&D for future NII services. High priority support continues to be needed in the five year strategic planning process which the CIC is currently pursuing.**

High priority research and development areas should address:

- ease of use to make services accessible by users with widely varying skills, experiences, abilities and backgrounds;
- interoperability among heterogeneous services;
- security and privacy technologies to provide cost effective, easy to use services at appropriate levels of security; and
- portability, mobility and ubiquity to enable users access independent of location.

This research would involve advancing the state of technology in such areas as data and knowledge management, multimedia search and retrieval, human-computer interfaces, language translation, and object technology.

- **Recommendation 2: The coordinated government-wide R&D strategy of NII services which is being developed by the CIC should continue to be closely**

coordinated and integrated with the progressive technology acquisition and deployment strategy being developed and implemented by the IITF.

The services strategy should include the development of pilot applications built on common services that address government problems and have significant relevance to the private sector. Development of the services strategy should be via an open process and involve the widest possible industrial and academic communities. The government should encourage and cooperate with industry to advance dialog and activity on creating a coherent services infrastructure. In particular, it should challenge the private sector to continue efforts such as those begun with the R&D and the NII Forum[4] to suggest specific research goals and programs and to facilitate technology transition from R&D to implementation and operations. Since government will be a major NII user, services research should also take into account government's unique needs.

• **Recommendation 3: Government, industry, and academia should work closely together in pursuit of an advanced architectural framework for the NII services layer that supports interoperability while enabling individual, commercially competitive solutions.**

The TPWG and the CIC should continue supporting activities for development of an advanced, interoperable architecture for the NII services layer. High priority support for this goal continues to be needed in CIC's five year strategic planning. The TPWG's Standards Project is developing a process for a more flexible Government policy for procuring NII products and services. The TPWG Standards Project will:

- identify the key interfaces for standardization which would enable the existing and emerging information infrastructure for communications, computing and entertainment arenas to interoperate;
- identify the processes (including informal and best practice) being effectively used by these arenas to implement *de facto* and *de jure* standards; and
- identify how the government will describe appropriate standards selected for their use in the information infrastructure.

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APPENDIX 1

Representative High Performance Computing, Communications, and Information Technology's Information Infrastructure Technology and Applications (IITA) Tableau of Services

Universal Network Services: Techniques for improved ease-of-use, "plug and play" network interoperation, remote maintenance, exploitation of new "last mile" technologies like cable TV and wireless, management of hybrid/asymmetric network bandwidth, guaranteed quality of service for continuous media streams, and scale-up of network capabilities to dramatically larger numbers of users.

Integration and Translation Services: These services support the migration of existing data files, databases, libraries, and programs to new, better integrated models of computing, such as object-oriented systems. They also provide mechanisms to support continued access to older "legacy" forms of data as the models evolve. Included are services for data format translation and interchange as well as tools to translate the access portions of existing programs. Techniques include "wrappers" which surround existing elements with new interfaces, integration frameworks which define application-specific common interfaces and data formats, and "mediators" which extend generic translation capabilities with domain knowledge-based computations, permitting abstraction and fusion of data.

System Software Services: These include operating system services to support complex, distributed, time-sensitive, and bandwidth-sensitive applications such as the National Challenges. The services support the distribution of processing across processing nodes within the network, the partitioning of the application logic among heterogeneous nodes based on their specialized capabilities or considerations of asymmetric or limited interconnection bandwidth, guaranteed real-time response to applications for continuous media streams, and storage, retrieval and I/0 capabilities suitable for delivering large volumes of data to very large numbers of users. Techniques include persistent storage, programming language support, and file systems.

Data and Knowledge Management Services: These services include extensions to existing database management technology for combining knowledge and expertise with data. These include methods for tracking the ways in which information has been transformed. Techniques include distributed databases, mechanisms for search, discovery, dissemination, and interchange, aggregating base data and programmed methods into "objects," and support for persistent object stores incorporating data, rules, multimedia, and computation.

Information Security Services: These services provide support for the protection of the security of information, enhanced privacy and confidentiality for users of the infrastructure, the protection of intellectual property rights, and the authentication of information sources within the infrastructure. Techniques include privacy-enhanced mail, methods of encryption and key-escrow, and digital signatures. Also included are techniques for protecting the infrastructure, such as authorization mechanisms and firewalls, against intrusion attacks, such as worms, viruses, and Trojan horses.

Reliable Computing and Communications Services: These include system software services for nonstop, highly reliable computer and communications systems that can operate for 7 days a week and 24 hours a day. The techniques include mechanisms for fast system restart such as process shadowing, reliable distributed transaction commit protocols, and event and data redo logging to keep data consistent and up-to-date in the face of system failures.

APPENDIX 2

NII Forum - R&D for the NII: Technical Challenges, Services Research Recommendations

The TPWG, in cooperation with NIST and seven private sector organizations, cosponsored a forum on "R&D for the NII: Technical Challenges" at NIST on February 28 - March 1. The forum was attended by more than 300 industry, university and government technology experts that discussed the technical research issues that need to be addressed in the NII. The results of the workshop are documented in a report entitled "R&D for the NII: Technical Challenges."

The report considered ten technical areas:

1. Network Components and Protocols
2. Information Appliances
3. Information Access
4. Multimedia Information Technologies
5. Infrastructure for Application Development
6. Dependability and Manageability
7. Ease of Use
8. Interoperability
9. Security and Privacy Technologies
10. Portability, Mobility and Ubiquity

Although the Services layer was not explicitly selected as a technical area, reference to services and the functional requirements for services pervades the report. Virtually all of the discussions of Information Access, Infrastructure for Applications Development, and Ease of Use are related to some aspect of the services issues.

In the area of Information Appliances and Servers, the report emphasizes that in the future NII these units must accommodate extraordinary diversity in protocols, functionality and services, be highly scalable in cost and performance, be highly reliable and must be designed to be evolvable. The report states that techniques for building reliable services from a collection of servers will be a considerable issue because of the scale of future systems.

All of the key challenges relating to Information Access are related to services. The challenges were identified as:

- the creation of effective user interfaces that tolerate imprecise requests and make a myriad of information resources understandable;

- the creation of highly efficient, yet effective, methods for searching distributed information repositories to obtain answers to specific queries;
- the creation of large-scale information resources that assist users in understanding their content; and
- the creation of architecture's that enable the integration and interoperation of separately designed information resources.

The recommended research and development agenda to address these challenges spans the fields of databases, artificial intelligence, human factors and performance evaluation. Research requirements highlighted are:

- advanced query languages and capabilities that provide location-independent access, anticipate users' needs and assist the user in formulating precise requests;
- interfaces capable of adapting to user preferences, limitations and behavior;
- mechanisms for effective information filtering;
- sophisticated techniques for optimizing searches of large, mobile and distributed information resources, including capabilities for time-critical delivery of data and for handling conflicting responses or out-of-date data;
- information repositories that support the above capabilities; and
- translation methodologies, content languages and the development of application-specific ontologies that facilitate the integration and interoperation of multiple information resources.

The key Applications Development challenge highlighted is to create an infrastructure to support low-cost and rapid development of many applications. Specific requirements include interoperability and the need to leverage common solutions for security, dependability, ease of use, and distribution over heterogeneous systems.

The recommended approach is to provide functionality in the form of reusable objects that provide services. These objects can be used as software components by application developers. The suggested R&D agenda involves refining this approach and researching the requisite technologies which span the fields of software engineering and distributed computing. Key components of the agenda include:

- studies on test applications to refine the model of building NII capabilities from coarse-grain objects or services; and
- development of object system foundations including:

    - primitives for replication and caching of objects while maintaining consistency and managing persistent storage,

- new (hybrid) models for communication and coordination among the distributed components of an application,
- primitives for collaborative applications,
- server load-balancing brokers,
- visualization and performance tuning tools, and
- application construction tools.

Services related key challenges for developing "Ease of Use" technologies are developing interfaces that provide all users with equivalent access to information despite differences in their skills, experience, and cognitive capabilities. The recommended research and development agenda to address this issue spans the areas of psychology, sociology, and user interfaces. Recommendations include:

- in-depth psychological, social and cultural study of NII users to understand how individuals can navigate through the NII and to understand how to support various levels of multi-user collaboration.
- metrics and methods for evaluating the ease of use of NII applications and services; and
- development of a core set of user interface standards to enable easy-to-use services across different platforms.

The highlighted goal of Interoperability research and development efforts is to enhance the ability to compose NII subsystems into a single, acceptably seamless system. To achieve this goal, we must identify and define common generic and application- specific services that provide a range of functionality and develop mechanisms for making these services widely available in the "NII operating system."

Research is necessary in a variety of system-wide security issues including the development of a well-specified security architecture that facilitates both mandatory and discretionary security, risk assessment, and extensions as NII services and capabilities expand. Mechanisms for security management across network and national boundaries are needed, as is research in core security services, such as authentication, encryption, authorization and anonymous access, that scale to billions of users and/or terabit data rates.